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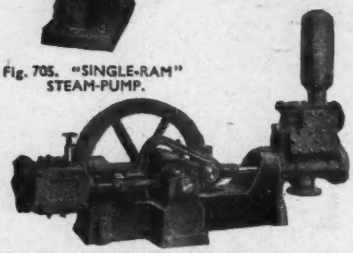

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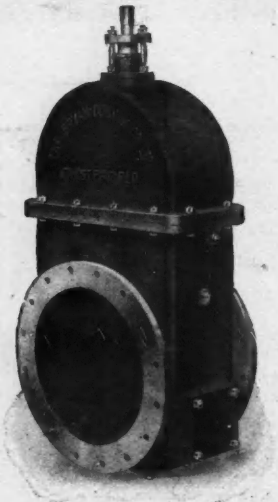

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CONTENTS

EDITORIAL NOTES

Gas as Prime Mover 101
Post-War Appliance Demand . . 102

Personal 102
Letter to the Editor 102

Institution of Gas Engineers . . 103
British Standards Institution . . 103
Diary 103
The Design of Distribution Systems to Supply Post-War Development. By H. J. Escreet, B.Sc.(Eng.), M.Inst. C.E. (*continued*) 104

"Infra-Red" by Gas. By L. W. Andrew, B.A., B.Sc., and E. A. C. Chamberlain, Ph.D., D.I.C., B.Sc., A.R.C.S. . 110

Gas Products Prices 116
Gas Stocks and Shares . . . 116

THIS WEEK'S ADVERTISERS

	PAGE
Aerospray Manufacturing Co., Ltd.	90
Aspinalls (Paints), Ltd.	118
Bagnall, W. G., Ltd.	94
Bale & Church, Ltd.	119
Birmingham Electric Furnaces, Ltd.	S6
Blakeley, Firth, Sons & Co., Ltd.	119
Bratt Colbran, Ltd.	95
British Thomson-Houston Co., Ltd.	97
Broadbent, Thos., & Sons, Ltd. ...	90
Bugden, Thos., & Co.	118
Cellactite and British Uralite, Ltd.	96
Cowan, W. & B.	Cover III
Crookston, S., & Co.	118
Curtis, A. L.	118
Dempster, Robert, & Sons, Ltd. ...	119
Derbyshire Silica Firebrick Co., Ltd.	S6
Donkin Co., Ltd. (The Bryan)	Cover II
Drynamels, Ltd.	S4
E. B. Refractory Cement Co., Ltd.	S4
Evans, Joseph, & Sons (Wolverhampton), Ltd.	Cover II
Falk, Stadelmann & Co., Ltd. ...	94
Fluxite, Ltd.	119
Gas Meter Co., Ltd.	S2
Gas Purification and Chemical Co., Ltd.	119, Cover I
General Refractories, Ltd.... ...	S5
Glover, George, & Co., Ltd. ...	89
Glover, Thos., & Co., Ltd. ...	100
Goodall, Clayton & Co., Ltd.	Cover IV
Green & Boulding, Ltd.	119
Hamilton, Archd. H., & Co., Ltd.	S6
Harrisons (London), Ltd.	119
Holmes, W. C., & Co., Ltd. ...	S1
Humphreys & Glasgow, Ltd. ...	98
Keay, E. C. & J., Ltd.	S8
Keith Blackman, Ltd.	S8
King, Geo. W., Ltd.	S4
King's Patent Agency, Ltd. ...	119
Main, R. & A., Ltd.	114
Menno Compressed Air Greasecup Co., Ltd.	119
Mewburn, Ellis & Co.	119
Mitchell, H., & Co.	118
Morton, Joseph, Ltd.	118
Newton Chambers & Co., Ltd. ...	108
Oxley Engineering Co., Ltd. ...	93
Parkinson, W., & Co.	100
Peckett & Sons, Ltd.	119
Pulsometer Engineering Co., Ltd.	Cover IV
Radiation, Ltd.	112, 113
Reavell & Co., Ltd.	118
Reinforced Concrete Association, Ltd.	92
Sawer & Purves, Ltd.	111
Slingsby, Walter, & Co., Ltd. ...	S2
Siebe, Gorman & Co., Ltd. ...	S6
Sperryn & Co.	99
Stanton Ironworks, Ltd.	120
Staveley Coal & Iron Co., Ltd. ...	S7
Stein, John G., & Co., Ltd. ...	97
Strachan & Henshaw, Ltd. ...	89
Sutcliffe Speakman & Co., Ltd. ...	S7
Thomas & Bishop, Ltd.	116
Trotter, Haines & Corbett, Ltd. ...	119
Turbine Furnace Co., Ltd. ...	S6
Walker, C. & W., Ltd.	111
West's Gas Improvement Co., Ltd.	117
West's Piling & Construction Co., Ltd.	Cover IV
Whessoe Foundry and Engineering Co., Ltd.	91
Widnes Foundry and Engineering Co., Ltd.	S3
Woodall-Duckham Co.	107
Trade Cards	116
Appointments Wanted and Vacant	119, 120
Contract Open	120
Patents	119
Plant, &c.	119
Plant, &c., For Sale and Wanted...	120

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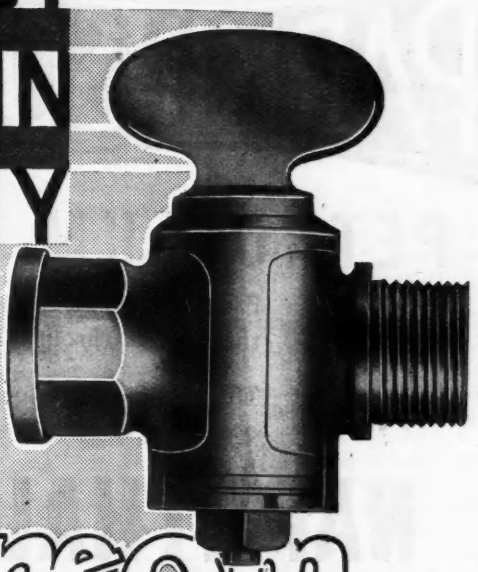

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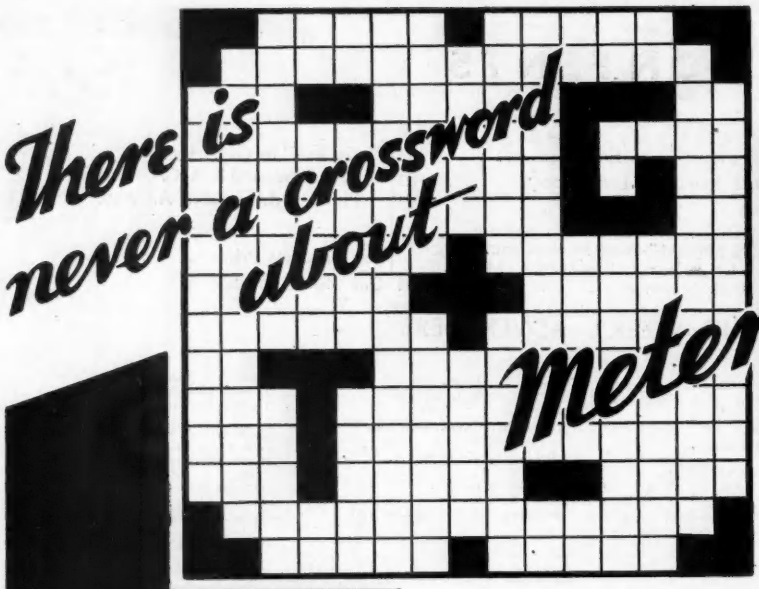

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GAS JOURNAL, JULY 28, 1943

VOL. 242 95th YEAR No. 4184

EDITORIAL NOTES

GAS AS PRIME MOVER

THE President of the Incorporated Municipal Electrical Association, speaking recently on the subject of co-operation between gas and electricity, suggested that the Gas Industry should seek to provide the electrical industry, for the generation of its current, with "heat units at the right price." The electricity supply industry, he argued, must have economic prime movers—*i.e.*, mechanical energy at no greater all-in cost than modern steam turbine and boiler plant—and it was up to the Gas Industry to encourage research into the production of an efficient and reliable gas turbine or other means of generating power. Perhaps what the President, who is Lincoln's Electrical Engineer, had in mind was that the Gas Industry should supply heat to the electrical industry so that, in turn, the latter could supply heat to the domestic consumer—which is a distinctly roundabout process. The nation's coal must be conserved. That is obvious enough, and it is equally obvious that the by-products of coal should be recovered, treated, and utilized to the best advantage. There are coals which lend themselves to carbonization; there are also coals which, though well suited for steam raising (and hence electricity generation), do not lend themselves to carbonization. Comparisons between gas and electricity should take account of this factor. Several comparisons drawn by enthusiasts in the Gas Industry seem to have ignored it, which is a pity and unquestionably weakens the gas case. Impartial fuel technologists know well enough that the Gas Industry would be reluctant to deal with many of the steam-raising coals which electricity uses quite efficiently for steam raising. We could develop this theme. But that is not the purpose of this note. We might, however, emphasize that the roundabout method of gas heat to electrical heat does not appeal to us overmuch, though we think it has limited application.

While saying this, we are sure that research on gas as a prime mover is eminently desirable. That is why we were so interested in Dr. J. G. King's comments last month on the matter ("JOURNAL" of June 30). He was referring to the possibility that the gas turbine holds out prospects which could reflect favourably on the Gas Industry. He explained the new principle, which is to couple to the turbine a compressor for compressing the air, the fuel being burnt in this air to raise its temperature before it passes to the turbine. With this method a thermal efficiency of 18% can be obtained, and by the addition of an intermediate re-heating stage and a heat exchanger this efficiency can be raised to 23%. And the Director of the Gas Research Board added that new advances in the manufacture of steel may make it possible to use higher gas temperatures. It may be possible to obtain very high rates of heat release in a small volume; the efficiency of the turbine itself is stated to be over 85%. Developments in the gas turbine might greatly increase the quantity of gas used for power production. But we ask whether gas resulting from carbonization, as distinct from gasification, should be used in this way. In other words, could no more useful and direct heating purpose be found for purified gas?

That is why we are not entirely in sympathy with Mr. T. A. Tomlinson, who, discussing the subject in the "JOURNAL" of March 3 last, quoted Mr. A. Stubbs (Metropolitan-Vickers) that "purified coal gas would be an ideal fuel for power generation in this country." We suggest that "purified" coal gas has a higher capacity for heat service than for the generation of power—and we really do mean "purified" coal gas, which the Gas Industry has had in its "power" so far with very little will to supply. "Purified" coal gas means next door to 100% utilization factor as a "district" background heater. Sulphur again? Yes. Perhaps, after the war, engine makers, too, may have something to say about sulphur-free gas.

Actually what has brought these thoughts to mind is yet another report just issued by the Association for Planning and Regional Reconstruction, whose activities were outlined in the "JOURNAL" of January 20 last, on the thermal efficiency of coal utilization in Great Britain. This report, after a brief world survey of energy resources, describes the present uses to which the British coal output is directed, and discusses the avoidable and unavoidable causes of waste. The field covered by the review is in truth vast, such subjects as the smoke problem, domestic heat requirements, the possible uses of ash, by-products, machines to use solar energy directly, development of tide, water, and wind power being included. The report is quite short, and we were very surprised, in view of the vastness of the field covered, to find that attention should be called to the suggestion ("JOURNAL" of October 7, 1931) that low-temperature radiation causes contraction of the nasal passages. For we doubt very much whether nose opening and closing will, post-war, decide the issue of the usage and expansion of gas and electricity, smokeless fuel and oil, and tidal and solar energy. However, the report is as adamant as we are that "*whenever possible a preliminary carbonization, with by-product recovery, should precede combustion.*"

We shall have more to say about the report later. We will confine ourselves at the moment to the single aspect of the use of gas as a prime mover. As is well known, the efficiency of the gas turbine is limited by the temperature of the gases after combustion, which in turn is limited, at present, to 1,000°F.–1,200°F. by the strength of the turbine blades. The temperature is kept down by using air largely in excess of that theoretically necessary for combustion. This air has to be compressed, and a considerable proportion of the power produced is absorbed by the compressor, causing a further drop in efficiency. Efficiencies up to 25 or 30% have been obtained by adding heat recuperators, and an alternative system in which the cooling is partly accomplished by allowing the gases to drive a compressor attains efficiencies of the same order. A dull recording of fact? If the mechanical limitations are overcome, we might be able to realize efficiencies of 40 to 50%, and it is rather interesting to contemplate the repercussion of such a development on other forms of power plant. Also, with the gas turbine, cooling water is not required. In electricity generation by steam, 55% of the energy in the coal is lost as heat in the cooling water, which is a large amount of energy. The possibilities of the gas turbine are fascinating. Yet there is no need to regard the future of gas as a prime mover as being bound up solely with the turbine. Only a fortnight ago we saw some recently installed gas engines which show very great improvements on pre-war engines and which to any engineer are good to behold. Believe us, development is both in the air—and in the gas engine. The particular engines we heard working with a gentle "purr" were supplied with "purified" gas—gas low in sulphur.

§§

POST-WAR APPLIANCE DEMAND

ON later pages we conclude publication of Mr. Escreet's extremely valuable Paper at the Institution meeting on the design of distribution systems to supply post-war development. Opening the discussion, which we give in full, Mr. Masterman, remarking that the demand for gas has doubled in the last 40 years, expressed his belief that it will redouble in a much shorter period, and to our mind everything points to the soundness of this belief. But, to translate anticipation into actual fact, we need to plan for a forward policy, for we have firm enough foundations for expecting to displace the use of much raw coal and to contribute to a much improved standard of heat services in the form of gas. Actually Mr. Masterman put forward as an immediate datum for planning a figure of 250 therms per consumer per annum, corresponding in the domestic field to cooking and a modest hot-water demand, or cooking and half the room-heating load. This seems modest enough. After the war advantage should be taken of the opportunity to undertake a much larger proportion of the supply of the heat services needed by the domestic consumer; and, looking ahead, it is well to remember that in the past the Gas Industry has had only about 20% of the load. The scope for development is apparent and it calls for tackling in a bold way.

At a conference of the Town and Country Planning Association this month Mr. F. J. Osborn spoke on housing demand. In Great Britain, he said, there are now about 13 million dwellings. Of these, 8½ millions date from before 1914; by 1964 none of these will be less than 50 years old. The great majority of these 8½ million dwellings are, or will be by 1965, unsatisfactory either in arrangement or in equipment, judged by current standards. From the point of view of quality of accommodation it would not be a disproportionate national programme to rebuild about 8 millions of our dwellings by 1964 or 1965—or twice as many as were built between the last war and the present one. We have mentioned these figures as an indication of the scope of development in which the Gas Industry should play a major part, and it calls for planning on broad lines; it demands the closest co-operation with housing authorities throughout the land, and the closest co-operation between the makers and suppliers of gas and the manufacturers of gas-consuming appliances.

The Gas Industry has undoubtedly a big programme ahead in the national service—a programme which will demand a large expansion in personnel, particularly on the distribution side. It seems to us that we shall need many more distribution engineers; as we said only last week, in the past "gas engineer" has connoted the works man to the detriment of the distribution side of the Industry's activities. Many distribution systems need remodelling. New and renovated works plant, ampler mains and services, and not least in importance, trained fitters and maintenance men—a small and efficient army of them. And how, we were asked by a gas appliance manufacturer recently, are we going to build up this trained army efficiently? Well, we suppose that first of all we shall have to have the men available, and to discuss this now quantitatively seems to be somewhat beside the point, which is the winning of the war, first in the West, and secondly in the Far East. The national claims on man-power are and will be more important than claims by the Gas Industry. Nevertheless, the Industry would be near-sighted if it failed now to give thought to the problem, to consider the claims which in the light of future circumstances it might reasonably stake, to take steps to avoid time lag in the launching of training schemes on a major scale based on pre-war experience, such as that of the regional plan operating so successfully at Watson House just before the outbreak of war, and to think hard on the question of how it can make itself attractive to those who, having doffed blue or khaki, seek a career of interest and promise providing adequate remuneration.

As we say, the authorities are unlikely at this stage of the war—and very wisely so—to commit themselves to any extent on the subject of demobilization, but this is not to prevent gas undertakings and appliance manufacturers, both severally and perhaps in consultation with one another, from taking stock of possibilities and at least visualizing the scale upon which plans will have to be made. We can imagine such consultation being helpful to both parties, especially when, so we believe, some of the larger gas undertakings are contemplating, for example, up to 20,000 cookers per annum to meet the immediate post-war demand. And it is not only the initial fitting which must be planned, but the complete organization which is covered by the word "service." In the circumstances which will face us after the cessation of hostilities, service may be regarded as beginning even before the installing of a cooker or other appliance. Local authorities or other undertakers of rehousing schemes will most certainly be in need of all the assistance they can be persuaded to accept, and the salesmanship which in the end pays best is sound advice rather than boost and blandishment. When we consider what dissipation of "sales" staffs (should we not rather call them "service" staffs?) has resulted from war conditions, we think that considerations such as those set out above should loom large in the post-war plans of individual gas undertakings.

Personal

Mr. E. V. EVANS, O.B.E., Chairman of the Gas Research Board and Immediate Past-President of The Institution of Gas Engineers, has been awarded the degree of Doctor of Science (*honoris causa*) of the University of Leeds.

* * *

Mr. H. E. BLOOR, who this month completed thirty years' service as Engineer, Manager, and Secretary of the York Gas Company, has relinquished the position of Secretary in favour of Mr. J. L. STEWARD, who has since 1936 been Accountant and Assistant Secretary to the Company. Mr. Steward served articles with Messrs. H. V. Wood & Co., chartered accountants, Huddersfield, and qualified as a chartered accountant in 1929, after which he was an accountant to the firm of H. W. Pulleyn & Co., until appointed to succeed the late Mr. E. Hardcastle in the services of the York Gas Company.

* * *

Following the death of Mr. J. R. George, J.P., Vice-Chairman, Mr. J. T. JOYCE, Engineer and Manager, has been appointed to fill the vacancy on the Board of the Weymouth Consumers' Gas Company. To mark the completion of 25 years' service with the Company, Mr. and Mrs. Joyce were recently the recipients of a gift of silver plate from the Board.

* * *

Mr. J. POLLARD, Deputy Engineer and Manager to the Burnley Gas Undertaking, has been appointed Engineer and Manager of the Darwen Undertaking. He succeeds Mr. T. HAWORTH, appointed to Wigan. Spending his professional career at Burnley, Mr. Pollard served as articled pupil in the Gas Department from 1926 to 1930, when he became Assistant Works Manager until 1933. Afterwards he was second Assistant Engineer and Deputy Gas Engineer and Manager from 1936.

* * *

The Inverness Town Council has appointed Mr. JOHN FORD Engineer and Manager of the Gas Undertaking in succession to the late Mr. Andrew Thomson. For the past 14 years Mr. Ford has been Assistant Engineer and Manager of the Undertaking.

* * *

Mr. EDWARD A. SMITH, Works Superintendent of the Eastbourne Gas Company, has been elected President of the Hailsham Rotary Club for the year 1943/44.

Letter to the Editor

"Mutual Help"

DEAR SIR,—It has always been my pleasure, as head of the Leeds Undertaking, to render mutual help from time to time—not only in connexion with air-raid damage, but also with any assistance for which I may be asked.

Some little time ago a certain gas-works in Yorkshire was in trouble, and in order to keep the supply of gas going, I was appealed to to send a gang of men, under my leading maintenance fitter, to help them out. Shortly afterwards the Manager of that works asked me if I would transfer my leading maintenance fitter permanently to his works; this, I might say, was after the man himself had been approached. I pointed out that we had only loaned him at considerable inconvenience, and that we were very short of labour in view of the large amount of machinery at our works.

The next step was an advertisement in the Gas Press for a chief maintenance fitter; then yesterday I was called upon to sign the release

form for the man we had loaned (which I did). I think my colleagues will agree that this is not the way to encourage "mutual aid."

City of Leeds Gas Department. Yours faithfully,
July 23, 1943. C. S. SHAPLEY,
Engineer and General Manager.

Institution of Gas Engineers

The Council of The Institution of Gas Enginers met in London on July 13, and the following are some of the matters dealt with:

The death of five members was reported, including Mr. J. McNicholl (Cork), a former member of the Council.

The membership of Committees of the Institution for 1943–44 and members to represent the Institution on kindred organizations for the year were reviewed and agreed.

Reports were made of the work of the Technical Committee of the Institution, with particular reference to recent meetings of the Gas Installations Committee (which is now engaged in the preparation of its final report for submission to the Ministry of Works in the near future), the Meters Committee (whose interim report was approved by the Council), the Liquor Effluents and Ammonia Committee, and the Joint Lighting Committee.

A report was made of a recent meeting of the Gas Education Committee.

Reports were made of meetings of the Post-War Planning Committee and of its Sub-Committees.

A report was made by the Chairman of the Council of the Gas Research Board of the work of the Board, with particular reference to the second annual general meeting of the Board held on June 10.

A report was made of the third meeting of the Co-ordinating Committee of the Gas Engineering Advisory Boards held on June 10. A further meeting of the Committee had been arranged for July 29, which would be attended by representatives of the Ministry of Fuel and Power.

It was decided not to hold an Autumn Research Meeting this year. Reports of the work of the Technical Committees of the Institution will be published in due course in the 4th Report of the Chairmen's Technical Committee. A Report of the work of the Gas Education Committee will also be published.

The resignation of Mr. R. J. Rogers (Birmingham), Chairman of the Gas Installations Committee, from the Chairmanship of the newly formed Codes of Practice Sub-Committee convened by The Institution of Gas Engineers at the request of the Ministry of Works, was received with regret. Lt.-Col. F. J. Bywater, M.C., had agreed to serve as Chairman of the Sub-Committee and, with Mr. G. C. Holliday, would in future represent the Institution on the main Codes of Practice Committee of the Ministry.

The resignation of Dr. W. E. le B. Diamond from the Assistant Secretaryship of the Institution, on his appointment as General Manager of the British Plastics Federation Limited, was received with regret. The congratulations of the members of Council were conveyed to Dr. Diamond on his new appointment. An approved notice inviting applications for the appointment of Assistant Secretary has been inserted in the daily and technical Press.

British Standards Institution

The Annual General Meeting of the British Standards Institution was held on July 20, following a luncheon at which the Rt. Hon. Mr. Hugh Dalton, M.P., President of the Board of Trade, was the principal guest.

The Chairman, Sir Percy Ashley, K.B.E., C.B., said that 230 new and revised British Standards had been issued during the past year. The total number of British Standards now in use numbered 1,500, all of which could be consulted at the Library of the Institution, where copies of Overseas Standards are also available.

In the course of his Address the Chairman said that the constitution of the Institution provided flexibility and adaptability which had enabled it to make a powerful contribution to national efficiency, a contribution all the more effective because in the main it had been devoid of any element of compulsion, but had been based on the principle of consent and voluntary co-operation with Government encouragement and assistance, but without Government control.

He added: "I believe that those industries which have been long and closely associated with the development of the Institution recognize fully the advantage of having a single independent, national standards organization. But those others which are only now beginning to consider the opportuneness of the time for a standardization programme covering types and sizes, trade terms, definitions, and performance standards, may feel that the preparation and promulgation of standards is a matter of domestic concern, and should therefore be carried out by their individual trade associations. There has also been some tendency for Government Departments to do standardization work in their own ways and on their own lines. I believe that both these courses are wrong in principle, and that the best results for any industry, and certainly for the industry of the nation as a whole, will be obtained only if all this work is carried on within a national organization such as the British Standards Institution, which can co-ordinate and guide all such action to a common end."

Dr. E. F. Armstrong, F.R.S., the Chairman of the Finance Committee, in presenting the accounts, explained that during the year under review the contributions to the expenses of the Institution amounted to £53,000, which was an increase of 20% over the previous year. The distribution of British Standards had gone up 57%. As the contribution made by His Majesty's Government depended on the extent to which industry contributed, he trusted that with the ever-widening scope of the work more industrial firms would become contributing members.

Diary

Aug. 10.—National Federation of Gas Coke Associations: General Committee, Gas Industry House, 10 a.m.

Aug. 16.—London and Counties Coke Association: Finance Committee, 11 a.m.; Executive Committee, 11.30 a.m.; Central Committee, 1.30 p.m.; Gas Industry House.

September 3.—North British Association of Gas Managers: Annual Meeting, Glasgow.

Figures Issued by the Metallurgical and Chemical Branch of the Dominion Bureau of Statistics, Ottawa, covering the year 1942 show that in the Canadian coal-tar distillation industry there was no change in the number of operating plants, but production was 32% more than in 1941. Output of creosote and other heavy tar oils increased between the two years from 12 to 15 million gall.; and production of pitch advanced from 85,113 tons to 91,717 tons, but the quantity of refined tars made, at 5.3 million gall. in 1942, was 1.5 million gall. less than in 1941.

A Saving of 1,000,000 tons of coal per annum has been effected since the Scottish Fuel Efficiency and Economy Committee was set up. This was stated by Sir Patrick Dollan when the Scottish Fuel Efficiency and Economy Committee reviewed the results of the fuel conference held in Glasgow. The Engineers' Panel was present, and added practical suggestions for use in connexion with the intensified economy campaign which is being prepared for the autumn and winter. It was urged that the prices of the so-called "inferior fuels" that engineers have recently been experimenting with should be brought under stricter control, so that firms undertaking to adapt their plants to save high-grade fuel would not have their plans upset by wide variations in costs. Fuel charges should, it was thought, have some regulated relationship to the calorific value of the fuel offered, otherwise those attempting their use in the national interests of coal economy might be involved in considerable financial loss.

The Title of the first of the series of Stevens Memorial Lectures which, as announced last week, Dr. J. G. King, Director of the Gas Research Board, is to deliver to the Junior Institution of Engineers on May 5, 1944, has now been changed to "A Survey of the Production of Tars and Oils from Coals." Informing us of this alteration, Mr. G. W. Germain, Secretary of the Institution, mentions incidentally that the Institution was founded in 1884 and therefore does not celebrate its Diamond Jubilee until next year.

Economy in Solder and Labour is effected by a spigot and socket lead joint developed by a large gas undertaking and described in a leaflet issued by Abbott, Birks & Co., Ltd., 90–91, Blackfriars Road, S.E. 1. While the principle is not new, the method shows a substantial saving compared with the wiped joint and the cup and cone type. It is claimed to be much neater than these two types of joint, and tests have proved it to be stronger than the actual pipe, both in hydraulic pressure and tensile tests. In this joint the pipe is opened out by means of a specially-shaped mandrel to form a socket of a size suitable to give a close fit between the pipe or brass fitting to be joined. The joint is then heated and the very small annulus filled with solder in the same way as with the cup and cone joint. It is stated that the saving in solder can be as much as 95%.

Her Majesty the Queen personally congratulated the Women's Gas Council upon an excellent home economy display which it staged at a Domestic Front Exhibition organized by the Middlesex Federation of Women's Institutes at the Middlesex Guildhall, Westminster, on July 20. Mrs. G. Abbott, Acting Secretary, was among those who were presented to Her Majesty in the main hall, where needlework, "Make Do and Mend" items, salvage, and general household equipment contributed by the various women's movements in the county illustrated the housewife's part in the war effort. The W.G.C. exhibit was staged in one of the committee rooms, and while the Queen was learning how the woman in the home is taught to make the most of the minimum amount of gas, Lord Woolton was inspecting a nearby display of wartime food. Her Majesty closely inspected a cooker oven containing a joint, vegetables, meat pie, milk pudding, fruit, and cake, and remarked that it was a marvellous example of economy in fuel, food, and labour.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in the "Journal" should not be taken as an indication that they are necessarily available for export.

THE DESIGN OF DISTRIBUTION SYSTEMS TO SUPPLY POST-WAR DEVELOPMENT

Institution of Gas Engineers, July 9.

By H. J. ESCREET, B.Sc.(Eng.), M.Inst.C.E.,
Distributing Engineer, Gas Light and Coke Company

(*Continued from p. 83*)

Comparison of Costs for Low-Pressure and Intermediate-Pressure Systems

The estimated costs of the local distribution at low and intermediate pressures are set out in Table 6.

The lengths and sizes of local mains for low-pressure supply, as shown on the left of Table 6, are actual figures for the mains as laid in the town. The length of mains for the intermediate systems are scaled from the plan of the town.

The costs are actual average costs of mains as given in the Paper on "Distribution of Gas in Surburban and Rural Areas."* The costs for the low-pressure system are those of cast-iron mains, those for the intermediate system are for steel mains. It will be seen that the total capital costs for the intermediate system are slightly lower than those for the low-pressure system, but owing to the higher cost of maintenance of the service governors the annual charge is 0·19d. per therm higher for the intermediate system than for the low-pressure system.

Comparison of Costs of Supply at Intermediate and Low Pressure

In the preceding sections of this Paper the various sections of the distribution system from the source of supply to the inlet of meter have been dealt with, and the cost per therm for each section calculated; these costs are summarized in Table 7. For each type of system the costs for local distribution and local storage and/or trunk mains are constant, irrespective of the distance from source of supply or size of town. These figures are shown in the first two lines of the table, followed by the transmission costs of 10, 25 and 50 miles for "large" and "small" towns, and the total costs of supply for each case.

Considering first the town of 25,000 houses, the costs of distribution at low pressure (types A, D and D1) are practically the same at 10 miles whether or not local storage is provided. At 25 miles, supply through storage is about ½d. per therm cheaper and at 50 miles nearly 1d. per therm cheaper. Although the cost of supply through six holders is 0·1d. per therm higher than for a single holder, it is considered that the advantages of small units for maintenance purposes offset this small extra cost.

For distribution at intermediate pressure, the costs of direct supply (type B) and supply through high-pressure storage (type C) are practically the same at 10 miles, but supply through storage becomes relatively cheaper as the distance of transmission increases, the difference at 50 miles being 0·8d. per therm.

Comparing distribution at intermediate pressure with distribution at low pressure, the intermediate system costs about ½d. per therm more at 10 miles, but at 50 miles the intermediate supply through storage (type C) costs only 0·2d. per therm more than low pressure (type D). The need for service governors on the intermediate system accounts for an annual charge of 0·49d. per therm; if this charge were excluded the costs for type C would be equal to or less than the costs for other types of system at all distances.

The foregoing comments as to comparative costs apply equally to the town of 5,000 houses, although in all cases the costs per therm are higher. It is unlikely that such a small town would be supplied from a source more than 25 miles away, and therefore the high costs shown for 50 miles would not be incurred in practice.

TABLE 7.—*Summary of Costs of Supply, in pence per therm*

Type of System	A	B	C	D	D_1
	Direct supply to low-pressure distribution system	Direct supply to intermediate-pressure distribution system	Supply through high-pressure storage to intermediate-pressure distribution system	Supply through six low-pressure holders to low-pressure distribution system	Supply through one low-pressure holder to low-pressure distribution system
1	2	3	4	5	6
Local distribution (Table 6)	1·23	1·42	1·42	1·23	1·23
Local storage and/or trunk mains (Table 4)	0·27	0·22	0·60	0·63	0·53
	1·50	1·64	2·02	1·86	1·76
Town of 25,000 houses :					
Transmission (Table 1)					
10 miles	0·70	1·03	0·66	0·34	0·34
25 ,,	1·54	1·71	0·89	0·72	0·72
50 ,,	2·42	2·47	1·27	1·22	1·22
Total costs					
10 miles	2·20	2·67	2·68	2·20	2·10
25 ,,	3·04	3·35	2·91	2·58	2·48
50 ,,	3·92	4·11	3·29	3·08	2·98
Town of 5,000 houses :					
Transmission (Table 1)					
10 miles	1·12	1·49	1·04	0·77	—
25 ,,	2·59	2·69	1·77	1·67	—
50 ,,	4·54	4·62	3·02	2·92	—
Total costs					
10 miles	2·62	3·13	3·06	2·63	—
25 ,,	4·09	4·33	3·79	3·53	—
50 ,,	6·04	6·26	5·04	4·78	—

Conclusions

The supply to new towns at some distance from existing gas distribution networks raises two problems:

(i) Should local storage be provided?

(ii) Should local distribution be at low or intermediate pressure?

The advantageous effect of local storage on transmission costs has been demonstrated in this Paper, and the further advantage of security of supply should leave little doubt as to the need for providing local storage in every case if the distance of trans-

* Escreet, H. J., *Trans. Inst. Gas Eng.*, 1936-37, **86**, 908.

TABLE 6.—*Summary of Estimated Costs of Local Distribution at Low and Intermediate Pressures*

Existing Low-Pressure System	Capital Cost £	Annual Charge: Rate, per cent	Annual Charge: Total, £	Annual Charge: pence per therm
Mains (cast iron) : £				
4-in. 49 miles at £924 = 45,300				
6-in. 30·3 ,, ,, £1,408 = 42,700				
8-in. 6·5 ,, ,, £1,584 = 10,300				
12-in. 8·9 ,, ,, £3,168 = 28,200				
	126,500	8	10,120	0·88
Services :				
25,000 at 40 ft. at £2 each	50,000	8	4,000	0·35
Total	£176,500		£14,120	1·23

Proposed Intermediate-Pressure System	Capital Cost, £	Annual Charge: Rate, per cent	Annual Charge: Total, £	Annual Charge: pence per therm
Mains (steel) : £				
2-in. 78·7 miles at £660 = 51,942				
4-in. 16 ,, ,, £1,100 = 17,600				
	69,542	8	5,563	0·49
Services :				
25,000 at 40 ft. at £2 10s. each (including stop-cock and surface box)	62,500	8	5,000	0·44
Service Governors :				
25,000 at 30s. each	37,500	15	5,625	0·49
Total	£169,542		£16,188	1·42

mission is 10 miles or over. The question of whether the storage should be at high or low pressure depends partly on the decision as to problem (ii), and partly on the volume of storage to be provided—the extra cost of high-pressure storage over low-pressure becomes less as the size of holder required decreases.

As regards the second question, it has been shown that the capital cost of an intermediate-pressure system, including service governors, is slightly less than that of a low-pressure system, but that the cost of maintenance of the governors results in an extra annual charge of about ¼d. per therm for the intermediate system over that for a low-pressure system. As a set-off against this extra charge there is better service to the consumer, and a much greater flexibility as to mains capacity. It may well be that with increasing loads it will be found essential to provide service governors on existing low-pressure systems because the endeavour to maintain constant pressure for the consumer greatly restricts the use of mains. It is to be remembered that flow through a main must result in a drop of pressure along the main, and that the so-called ideal distribution system in which pressures are maintained constant could only function at one rate of flow. Variation in load must result in variation of pressure, and if this variation is to be kept within very small limits either the volume supplied must be small or the mains large. The use of service governors enables the mains capacity to be increased by increasing pressure drops in the mains without causing variations in pressure at the consumer's meter.

If it be admitted that a low-pressure system must be provided with service governors so that considerable pressure losses in the mains may be allowed, then that system becomes in effect an intermediate-pressure system, and in planning new systems advantage should be taken of the opportunity to save capital expenditure by using smaller mains and working at pressures within the range of 1 to 10 lb. per sq. in.

Appendix 1

Variation of Initial Pressure with Terminal Pressure

The following table shows the initial pressures required for the transmission of 115,000 cu. ft. per hr. over distances of 10, 25 and 50 miles at terminal pressures of 1 lb. per sq. in. and 60 lb. per sq. in.

Diameter of Main		4-in.	6-in.	8-in.	10-in	12-in.
Length of Main, miles	Terminal Pressure, lb. per sq. in.	Initial Pressures, lb. per sq. in.				
1	2	3	4	5	6	7
10	1	189	62	26	12	6·4
	60	201	92	69	63	61
25	1	306	105	47	23	12·6
	60	314	126	81	68	63
50	1	439	155	71	37	20
	60	445	169	98	74	66

It will be noted that the loss of pressure in transmission is very much less for a terminal pressure of 60 lb. per sq. in. than for one of 1 lb. per sq. in., and this is especially marked when the loss of pressure for a low terminal pressure is high, e.g., for a 4-in. main, 50 miles in length, the increase of terminal pressure from 1 lb. per sq. in. to 60 lb. per sq. in. only increases the initial pressure by 6 lb. per sq. in.

This effect may readily be deduced from the high-pressure formula for flow in pipes:

$$Q = 2{,}675\sqrt{\frac{d^5(p_1^2 - p_2^2)}{SL\zeta p_a^2}}$$

which may be transposed to

$$(p_1^2 - p_2^2) = \frac{Q^2 \cdot SL\zeta p^2}{(2675)^2 d^5}$$

For a given quantity of gas, length of main, diameter of main and quality of gas, the expression on the right-hand side is constant, and therefore $(p_1^2 - p_2^2)$ is constant but $(p_1^2 - p_2^2) = (p_1 - p_2)(p_1 + p_2)$.

Since p_1 must increase with p_2, $(p_1 + p_2)$ increases with increase in p_2 and therefore $(p_1 - p_2)$, the difference in pressure or loss in transmission, must decrease when the terminal pressure p_2 is increased.

Another factor favouring transmission over a high range of pressure is the reduction in rate of increase in power required for pumping as the pressure is increased, e.g., an increase of 10 lb. per sq. in. from a pressure of 10 to 20 lb. per sq. in. requires an increase of 0·75 h.p. per 1,000 cu. ft. pumped, while for an increase from 70 to 80 lb. per sq. in. the increase in h.p. per 1,000 cu. ft. is only 0·3. Thus not only does $(p_1 - p_2)$ decrease as p_2 increases, but the increase of power required to pump over the range $(p_1 - p_2)$ also decreases.

It is for these reasons that it would be uneconomical to transmit the gas at a low terminal pressure and then pump it into high-pressure storage. As an example, the cost of transmitting 115,000 cu. ft. per hr. for 10 miles, at a terminal pressure of 60 lb. per sq. in., is shown in Table 1, col. 8, as 0·66d. per therm while for a terminal pressure of 1 lb. per sq. in. the cost is 0·34d. per therm—a difference of 0·32d.

If the gas were transmitted against the lower pressure and then re-pumped to 50 lb. per sq. in. at each of the five holder stations, the gas to be pumped at each station would be 23,000 cu. ft. per hr. and the pumping plant required would be of 72 h.p.

Cost of pumps would be	£2,500
Interest and depreciation, at 15 per cent	375
Cost of pumping—	
5,000 hr. at ¼d. per h.p. hr.	749
Total pumping cost	£1,124

This would be for $\left(\frac{2{,}750{,}000}{5}\right)$ therms per annum, or a charge of 0·49d. per therm. This is 0·17d. per therm greater than the difference in transmission cost and at greater distances the difference between transmission costs is less.

Similarly, for pumping to 12 lb. per sq. in. for the direct supply to intermediate distribution system the cost of pumping on site would be 0·56d. per therm, which is again greater than the difference in transmission costs for terminal pressures of 1 lb. per sq. in. and 12 lb. per sq. in. for all distances.

Appendix 2

Pressure Loss on a Main Distributing Gas at regular intervals along its Length

Using the flow formula $Q = K\sqrt{\frac{hd^5}{SL}}$ it may be shown that the pressure loss h_T in a main from which gas is being distributed at frequent and regular intervals along its length, the same volume being supplied at each interval and the final flow being nil, is one-third of the loss h as calculated from the formula, when Q is the volume entering the main, i.e., $h_T = \frac{h}{3}$.

When using the more accurate formula $Q = K\sqrt{\frac{hd^5}{\zeta SL}}$ allowance must be made for the variation in the value of ζ. Since the value of ζ increases with reduction in rate of flow, this variation cannot be ignored when the flow changes from that corresponding to Q at the beginning of the main to zero at the end. The true value of h_T must therefore be in excess of $\frac{h}{3}$.

The Author has been unable to deduce any formula for h_T which takes into account this variation of ζ but from a number of test calculations it has been found that approximate values are

$h_T = \frac{2}{5}$ h if ζ is calculated from the value of Q.

or $h_T = \frac{h}{3}$ if the value of ζ used in calculating h is that corresponding to $\frac{3}{5}$ Q.

DISCUSSION

Mr. C. A. Masterman: The demand for gas has doubled in the last 40 years. I anticipate it will re-double in a much shorter period. This expectation is the logical consequence of comparative costs of supply, and of the conviction that a public familiar with convenient forms of transport, communications, and entertainment will not tolerate inconvenient heat services in post-war homes and factories. The distribution engineer will have to enlarge both the capacity and length of his mains.

I am therefore disappointed that the Author derived his distribution costs per therm on the pre-war basis of only 110 therms per consumer per annum. This corresponds to not much more than the cooking load alone, and on that basis costs are high. If we base our charges on high costs we contract the field within which consumers will use gas. Indeed we may not even realize 110 therms per consumer, and in point of fact the total increased gas sales between 1927 to 1937 spread over the two million odd additional consumers averages less than 80 therms per consumer. If we plan for stagnation we might achieve oblivion.

May we not rather plan for a forward policy, such as the facts fully justify? Our cousins, the electrical industry, have found planning on what we might consider a wildly optimistic scale to be on balance a good thing. We have firmer foundations than have they to expect to displace the use of much raw coal, and to contribute to a much improved standard of heat services in the form of gas. I do not accept a fifth only of the domestic heat load as the best that gas can do. I would urge as our datum for the time being 250 therms per consumer per annum, corresponding in the domestic field to cooking and a modest hot-water demand, or cooking, and half the room-heating load. Our distribution load factor would be much better than on cooking alone, so that distribution costs per therm would be then about one-third of Mr. Escreet's figures. Surely if we can fix charges on that basis we can get the additional consumption, whereas by fixing our charges on a more conservative basis we may well strangle expansion.

If the Industry believes in its own progress and if its claims to provide greater service after the war are sincere, it should make its plans and draw up its estimates accordingly.

Mr. Escreet's conclusions are consistent with that approach. He looks to higher pressures, which at once provide us with flexibility to meet heavier gas demands in the future. The crux lies in the provision of service governors. If it became an accepted standard in the Industry that the maximum pressure at the consumer's meter should not exceed the minimum by more than, say, 50%, the use of service governors would become general. In the past we may have had only few complaints on the score of pressure variation, but this is due to the public accepting them as an inevitable feature of gas supply, to be avoided only by change to other fuel. Encouragement of complaints and a check-up with maximum-minimum pressure gauges would often expose a sad state of affairs. So I sympathize with the Author that governors are an essential part of good service, though I seriously quarrel with the high maintenance costs he estimates of 3s. a year based presumably upon their exceptional use. As a standard part of installation, the meter reader can give them the very small amount of attention necessary at very few pence per annum. In new houses, adequately carcassed, service governors would ensure constant pressures at all appliances, and would be cheaper than governors integral with the appliances, of which immense numbers were installed before the war as alone able to compensate for pressure losses within the house. But if integral governors be abolished, there requires to be national agreement to some code governing the outlet pressures from service governors, if we are to avoid going back to the local manipulation of pressure adjustments on the appliances. For the time being I would therefore retain the use of integral governors, which we know more than pay for themselves, while welcoming the widespread introduction of service governors. The additional all-in cost of these I estimate, gross, to be very much less per therm even than the Author's figure, at which they would still be good value for service rendered.

By their use we gain two essentials. First, we obtain correct and sufficient pressures at all times for consumers' needs; second, we much increase the capacity of existing mains by the use of higher pressures to meet the increase in demand for which we must plan. May we take double the present average consumption per consumer as the first step?

Mr. K. Tate (Wandsworth): The Wandsworth undertaking, whose area approximates in shape to that of a right-angle triangle, with the chief manufacturing station in the upper corner, has long been interested in an ever-extending system of supply by pressure, termed in the Paper as "intermediate," and although existing development is not such as to justify gasholders every ten miles, the provision of such district holders along our trunk mains is the ultimate aim. Recent extensions have, in fact, been designed to handle peak loads for the next few years until such holders can be installed, when, of course, future peaks are covered for some long period.

There can be little doubt, after reading the Paper, that future distribution lay-outs in new towns should incorporate an appropriate number of district holders whether of high or low pressure, and the relative merits financially of the two systems are similar. There are, however, other aspects of these alternatives which could usefully be considered. Many specimen plans of new towns incorporate very definite underground conduits for public utility services, and there can be no doubt that in such towns of the future the position of a gas main will be dictated by the local authority. Under such conditions the adoption of gas mains of only 2-in. and 4-in. diameter, as for an intermediate pressure distribution scheme, would seem very desirable. On the other hand, there is more chance of gas escapes from higher pressure supplies, with resultant dangerous conditions in such conduits, and to avoid these, a very high standard of workmanship will have to be maintained.

I am also rather concerned about the difficulty of maintaining and repairing pipes laid universally in narrow and possibly congested or waterlogged ducts when these pipes are welded steel, as opposed to cast iron, and the adoption of the former in any large degree will undoubtedly lead to a marked change in main-laying technique.

The Author has argued very convincingly for a service governor, but there remains a considerable body of opinion in favour of the appliance governor as being the ideal, and surely for low pressure supply, the only necessary, control.

The flexibility and the reserve for the future inherent in an intermediate pressure system of local supply are two assets of the greatest value, but the adoption of the system requires the closest co-operation with both architects and builders in order to arrange for the positioning of meters and service governors. Such co-operation should be easily obtained in our brave new world, but I have a distressing picture in my mind of the consequences of a number of high-pressure service governors working improperly, and then all venting together into some confined space, such as the well of a large block of flats. Cannot the normal high-pressure service governor venting to atmosphere when it fails to close properly and the outlet pressure builds up, be superseded by a combination of governor and excess pressure cut-off valve all in one? Such an ambition might increase the cost per therm of distributing gas by intermediate pressure by some 0.20d.

The Author's suggestion that the annual charges on both cast iron and steel mains are the same (see Table VI) is optimistic, but in comparison with low-pressure distribution, any additional costs under this heading would probably be more than equalled by the labour costs in operating the numerous low-pressure district holders for which I cannot find provision in the various estimates.

In conclusion, I would remark on two other problems which loom largely in the distribution engineer's mind. There is the possibility—and it is to be hoped probability—of greatly increased loads on existing low-pressure distribution systems. As lately as May 30, the Minister of Labour and National Service stated in an interview that refrigerators and all the various labour-saving domestic appliances must be made available to all levels of the community for general use after the war. The problem of meeting this additional load, the obtaining of which is so essential to our Industry, is a difficult one, and the alternative of stressing an existing distribution lay-out, or laying feeder mains to selected points, is complicated by the necessity of operating much higher pressures, even in service pipes.

Secondly, we all wonder where and how the new building development is going to take place. In an attempt to probe the future, I have studied the Scott, Uthwaite, and Barlow Reports, and with the help of the Land Utilization Survey have examined my Company's area for sites of potential building developments. The attempt was not a success, largely because of the somewhat conflicting aims of the Committees of investigation whose reports were examined, and so, even now, when the development of distribution systems is continuing day by day, we do not know whether to plan for the present and immediate future, or for a future which must materialize nationally but not necessarily locally, and thereby within any of our personal jurisdictions.

Mr. J. H. Dyde (Uxbridge): We all know that distribution problems are essentially individual in character, and to design a system certain facts must be known or assumed. In developing his treatise Mr. Escreet has taken the supplying of a new satellite town of 100,000 inhabitants, 25,000 consumers, and 110 therms per consumer, and he has shown how a town of similar size was dealt with in the pre-war period, how the problem would now be met, and at what cost, if gas had to be transmitted ten, twenty-five and fifty miles to a direct low-pressure system, to a direct intermediate pressure system, and, alternatively, through low-pressure and high-pressure storage. He has revealed the relative flexibilities of the alternative means of supply by assuming an increase of 100% in load, and he has dealt fully with local trunk and supply mains at both low and intermediate pressures. The picture, therefore, for the set of conditions Mr. Escreet has assumed, is complete and comprehensive.

I have made the following brief notes concerning specific points raised in the Paper:

(1) *Transmission Costs.*—The Paper clearly shows the cheapest transmission at almost any reasonable distance is to low-pressure storage. This will cover the majority of cases where regional planning concentrates manufacture at the cheaper producing centres with the defunct works being retained as holder stations. In my own Company we have plans to close down two small rural and one medium size works, and have proceeded some way towards laying the necessary transmission mains to deliver into existing low-pressure holders. Other Companies, on amalgamations, have gone farther.

(2) *New Local Storage Stations.*—In supplying an entirely new area of some size, and remote from the producing centre, the advantages of local storage are so clearly brought out by Mr. Escreet as to leave little doubt that he favours such provision, although it would seem that he preserves an open mind as to whether this storage should be at high pressure followed by local distribution at intermediate pressures, or low-pressure storage followed by low-pressure local distribution. The sum total of distribution costs by all alternatives are, in fact, so close that local conditions would probably decide the issue; for instance, the proximity of suitable transmission mains and whether they already operate at low or high pressure, the peculiarities of the route for main-laying purposes, and the ease with which scheduling powers for storage can be obtained, &c.

In so far as the provision of low-pressure storage is concerned, I think it would be a mistake to rely on one district holder. In the Company I serve we have eleven district holders on seven sites, four holders being sited singly. One of these holders recently had to be shut down for repairs to the inlet main, and it was only with the greatest difficulty that gas supply was maintained, and that only at a cost of numerous complaints. Moreover, satisfactory painting of the lowest lifts has been found almost impossible by the necessity for holder movement.

On the other hand, the possibility of scheduling, say, six sites each to carry a 250,000 cu.ft. low-pressure holder round a newly-planned town, from an amenity point of view, would seem remote. Even a 250,000 cu.ft. two-lift holder in steel tank for an economic diameter-height ratio would be 65/75 ft. high when fully inflated, and from our experience it is difficult to screen such a holder with trees, always providing that the local soil is suitable. In the circumstances, it would seem preferable to provide two three-quarter million or three half-million holders grouped on scheduled land in the acknowledged industrial area of the new township. The grouping into somewhat larger units would also reduce supervision and painting costs.

(3) *Cost of Anti-freezing Protection.*—District holders can incur considerable expense during a prolonged cold spell—for instance, in the period Dec. 23, 1941, to March 8, 1942, the cost of maintaining as required an anti-freeze service to three holder stations each with single gasholders and totalling in capacity 1,145,000 cu.ft., was £295, being made up of labour £196 and fuel (coke) £99. It would seem that there is a case for automatic gas firing, particularly as labour has to be supplied at just the time when it is most needed on the district and works.

(4) *Local Supply at Intermediate Pressures.*—The king-pin to the development of this system would seem to be the efficiency obtained and servicing required of the medium-pressure service governor. The practical experience of engineers who have employed them on a large scale would be welcomed. Their successful use would go a long way to meeting the peak load that will be the inevitable result of our increasing space-heating commitments in the post-war period.

Lieut.-Col. **J. A. Gould** (South Suburban Gas Company): One hopes that co-ordinated schemes of re-housing on the lines Mr. Escreet visualizes in his introduction may take place. I cannot at present see, however, how after the war distribution engineers will be in possession of such complete information as to give them the opportunity of designing distribution systems to meet the probable development in their companies' areas, which is Mr. Escreet's expressed hope. From my own experience it is probable that there will be large housing schemes to plan for, but I expect that they will be located at different parts of the Company's area where land is available and will, in most cases, have to be considered in relation to the existing distribution system. The case Mr. Escreet has taken to illustrate his views is an unusual one. It is rare to be able to plan at one time the lay-out of a distribution system for 25,000 houses. This would, in the case of most ordinary companies, bring into the picture the necessity for laying a feeder main from a works or holder station, when the problem could then be considered on the lines suggested in the Paper. Our pre-war experience showed that housing schemes of over 3,000 houses were rare, and that they were dispersed throughout the suburban parts of the Company's district. My own view is that, generally speaking, the same state of affairs will exist after the war, and that it will be necessary to consider the areas in which building is likely to take place, having regard to means of transport, &c., available, and to secure well ahead sites for holders without restriction as to type. With these considerations in mind, the distribution system should be developed on the most flexible lines possible. My Company dealt with the problem of holder sites in 1935, when we surveyed the districts and obtained a number of sites for floating holders at nodal points. I would emphasize the importance of this step, as we had difficulties with the local authorities and other parties, who objected to holders of any type, and particularly to those of the low-pressure type.

For the reasons I have mentioned earlier, it is usually difficult to see so far ahead that an ideal distribution system can be planned for, and in the past we have found it necessary to lay mains (either low or high pressure) which can act as trunk mains while development is proceeding, and which can later be used to fill holders. We have in accordance with such arrangements utilized the works high-pressure inter-station mains by laying branches from them to feed governors at distant points, and later extended those branches into a works or holder station to become independent district feeder mains. They are laid with suitable joints to withstand high pressures, and thus full use can be made of them.

We have made use of small high-pressure storage stations, and actually have two operating at the present time (at one time we had four in use). They do not, however, fulfil the duty envisaged in Mr. Escreet's proposals, but are employed to feed into remote points on the Company's district during cooking peaks. They consist of cylinders 30 ft. by 8 ft. diameter, storing gas at 50 lb. per sq. in. They can only be filled by compressors on the spot when the pressure on the district permits, and here again they, too, serve a useful purpose in enabling the Company to meet its obligations—*e.g.*, in a case of ribbon development, or while the development of a part of the district is tentatively proceeding.

With regard to the considerations arising from distribution at high pressures in transmission mains, I think that the Industry should make up its mind generally on this point. In the case of the higher pressures Mr. Escreet has mentioned, which obviously necessitate the use of steel mains, is there any agreement in the Industry as to the desirability (all things being considered) of conveying gas at a pressure of, say, 100 lb. per sq. in., in mains running through towns? If so, is there any maximum which would be considered necessary in such circumstances? In a country road where there are no sewers, &c., in which gas escaping at such pressure could find its way, the problem is somewhat different. I am not nervous of high pressures, as we ourselves distribute at pressures up to 15 lb. per sq. in. through cast iron mains in the London suburbs, but this question of principle has not in my opinion been given full consideration.

There are, of course, difficulties with high and intermediate pressure supply mains when making connexions, &c. A good system of trench inspection is desirable with such systems. On the other hand, I think Mr. Escreet makes a very good point whem emphasizing the flexibility of such mains and the services connected to them. This brings me to the point he has made about the service governor. I agree that it is unfair to charge the high-pressure services with the cost of such governors, in favour of the low-pressure services without them. I think that his remarks regarding the impossibility of avoiding variations in pressure in a main system under varying loads are extremely important, although not always appreciated, and in a constantly developing district it is impossible to correct this state of affairs by enlargements of mains, &c. The Institution's Committee which reported on gas quality made recommendations on this matter, and they suggested as an alternative the installation of service governors. In both cases financial considerations assume great importance. I would mention that we have a small number of high-pressure consumers' service governors in use, working with inlet pressures up to about 10 lb. per sq. in. These are examined and maintained at six-monthly intervals, and we have no troubles with them at all. In some cases they supply public street lamps.

Referring to the general question of post-war development, particularly having regard to cost, I would emphasize the importance of studying the post-war planning report of the Institution of Municipal and County Engineers, and that of the Institution of Highway Engineers, both of which, in referring to mains, state that distribution mains should be in duplicate and laid in the footways, and both Institutions recommend the use of conduits to carry mains. The report of the former Institution emphasizes the necessity for town-planning authorities having powers to require developers to provide sites for substations, &c., for electricity undertakings.

In conclusion, I would urge the necessity in post-war planning for the position of the mains of the various undertakings to be agreed, particularly in respect of estate roads.

Mr. **F. H. Robinson** (Bishop's Stortford): In the Paper the ratio of the maximum day's consumption to the annual consumption is taken as 1 : 200. While this may be true of London, it is by no means true of other places. In my own undertaking the ratio is nearer 1 : 250, while in a small town which I visited recently the ratio was 1 : 280. Each town and district must therefore be considered on its merits.

The use of service governors for direct supply from high and intermediate pressure mains will ensure ideal conditions of pressure for the consumer if of the right type for the particular pressure employed. If, however, the pressure varies widely, the governor will not give satisfactory results.

The Author visualizes high-pressure supply commencing at over 60 lb. per sq. in. and finishing in some cases at 1 lb. per sq. in. when supplying direct to the district or into a low-pressure holder 50 miles away.

The orifice in the governors used on such a main must be proportioned to the inlet pressures within certain limits. A governor made to pass a certain quantity of gas at 50 lb. inlet pressure will not pass the same quantity at 5 lb., and I therefore suggest that on very long lengths of high-pressure main where a large drop in pressure is experienced, governors should be designed to function in ranges of 10 lb. per sq. in. if good results are to be obtained. This, of course, presupposes that the rate of delivery along the main is constant, as would be the case if holders were installed *en route* or at the end. If, however, the scheme is to supply direct into a district without local storage, and high pressure is used, then there will be trouble with pressures varying from 3 or 4 lb. at peak load to, say, 50 lb. during the off-peak period.

If I have read the Paper correctly, the Author has made out a good

case for intermediate pressures and local storage for all except very long lengths of main, on the score of both practical working and cost.

In order to limit pressures to the intermediate limit of 10 lb. per sq. in. to give the best results with consumers' service governors, one might consider the advisability of dividing very long lengths of transmission mains into sections with a few relay pressure stations at regular intervals instead of one pressure station at the inlet end only working at high pressure. A saving in the cost of mains might thereby be effected.

With the Author's suggestions of district holder stations for local supply, together with intermediate pressure ring mains, I am in complete agreement. Whether these district holders be of the low- or high-pressure type must be determined by local circumstances. Such a scheme provides the flexibility and reliability which are so desirable.

By providing storage at the end of a long main, a smaller transmission main from the works to the remote district is required than if there is no storage at the end. With a compressor at one end and a high-pressure holder at the other, the carrying capacity of the main during peak load is increased four-fold because the discharge varies inversely as the square root of the length. Pressures between are not, therefore, subject to such wide variations as would be the case if no holder were provided.

As to whether one large holder or an equal storage in a few small holders is better, there can be little doubt that the latter is to be preferred if the district is at all extensive. To have only one large holder in order to reduce the cost of storage per therm is saving on the holder in order to spend it on the district, and continuing the present undesirable pressure variations caused by distributing from one centre. I do not think we ought to dogmatize about the type of holder. Every district must be taken on its merits and the best scheme put forward.

In Table IV the difference in total cost for local mains and storage between one large low-pressure holder and five intermediate pressure stations is only 0.07d. per therm, which is very little to pay for the benefits received.

"INFRA-RED" BY GAS*

By L. W. ANDREW, B.A., B.Sc., and E. A. C. CHAMBERLAIN, Ph.D., D.I.C., B.Sc., A.R.C.S.

(Gas Light & Coke Company, Watson House).

RESEARCH and development on the utilization side of the Gas Industry has always been directed to improving the efficiency of gas-burning equipment, industrial and domestic. Fundamentally the problem is to discover ways and means of increasing rates of heat transfer. It was early recognized that the major obstacle to progress was the dead film effect always encountered in the transfer of heat by convection between fluid and solid. The high resistance of this boundary layer(1) could only be reduced by high rates of flow, or compensated by artificial increases in surface area by the use of devices such as fins. It was also recognized that heat transfer by radiation(2) had no such obstacle, and it was therefore obvious that possible improvements lay in the development of heat transfer by radiation. The specialized requirements of space heating led naturally to the development of gas sources of radiant heat, and the principles discovered have been applied with success to industrial furnaces, while a few specialized processes, such as ink drying, biscuit baking, and fur drying, requiring very high rates of heat transfer, had for many years relied on radiation from a gas source. It is not always appreciated that many existing appliances—for example, the steam tube bakers' oven—can legitimately be regarded as of the infra-red type.

Much work of a fundamental nature has been done in the Fuel Department at Leeds University on the problems associated with the emission and absorption of infra-red radiation, particularly regarding the sources of selective radiation. This, together with the work of the Gas Research Board, has been of great value in the development of gas sources of radiant heat.

The demand for very high rates of production of paint-finished articles during the war revealed, for certain processes, a serious bottleneck in the time required for the curing of paint in convection ovens, and it was natural that the great advantages of radiant heating should be considered as a possible solution to the problem.

The experiments described in this Paper show that gas has a most important part to play in the development of high rates of heat transfer by the use of infra-red. The Industry is particularly fortunate in the radiant heat sources available, the result of many years' research and experience with gas fires, the medium temperature panels used in space heating, and the development of high efficiency industrial furnaces making the maximum use of radiation from hot surfaces. Thus we have at our disposal highly efficient apparatus for this work, which is relatively cheap to construct, very robust, with high infra-red output over large areas without the use of costly reflectors. All these appliances require little or no maintenance.

The field for gas-heated radiant sources for paint drying is therefore very great, while the scope in other processes is rapidly becoming recognized. The application to heating liquids in glass containers and tubes, and the use of high intensity radiant heating for speeding up mass production brazing and soldering has already been accomplished.

The object of this Paper is to show what part gas can take in radiation (infra-red) heating, how it is particularly fortunate in the characteristics of the radiant sources available, and what are the practical considerations for the successful application of infra-red to drying processes.

Drying Processes

Since the chief use of infra-red is at the moment for paint drying, it is necessary to consider briefly this process. The large number of different types of paints and synthetic finishes makes paint drying a highly technical subject which can only be dealt with by the paint specialist, but it is necessary to distinguish between the three main types of coating which require heat:

(1) Paint in which a solvent is evaporated leaving an oleo-resin and a pigment ; the oleo-resin must then be oxidized to form a hard paint film.

This oxidation is very slow at a temperature of 100–180° F., but may be speeded up appreciably as the temperature increases. The drying process, however, still remains comparatively slow at temperatures below that at which burning of the resin and spoiling takes place. For example, one paint of this type dried at 200° F. in 2 hours, at 300° F. in 10 min., and spoiled in 2 min. at 350°F. before it dried.

(2) Lacquers in which a solvent is evaporated and no other change takes place. An increase in temperature, and in air circulation, assists in the removal of the solvent, and this type of paint rarely offers serious problems for speedy drying.

(3) Heat transformable paints, in which not only is a solvent evaporated, but there is also polymerization of the vehicle. This polymerization is a physico-chemical change in which simple molecules combine together to form complex molecules of the same chemical composition. The process is generally very slow at temperatures of 100–150°F., but above a critical temperature becomes very fast indeed. This temperature is less than that at which burning and spoiling of the paint occurs in a reasonable time. For example, one paint of this type required 1 hour to dry at 180°F., and only 1 min. at 230°F. The gloss of the surface, however, was lost after 5 min. at 230°F., but this 4-min. interval is a practical operating margin.

These three main types decide the most practical drying temperature and drying time at that temperature, but generally speaking it is possible to think in terms of a minute or less for lacquers and heat transformable paints, and 10 to 20 times as long for the oleo-resin types.

It must be quite clear that the drying temperature referred to here is the actual paint temperature.

The success of infra-red drying has, in part, been due to the development of the type 3 polymerizing finishes, and it must be recognized that though infra-red can greatly reduce the time required for drying other types of paint, the results are likely to be less spectacular, though still of considerable importance.

The three drying processes have in the past been carried out in convector ovens at temperatures of 250–350°F., and the time required has depended on the interval taken for the object painted to reach the drying or curing temperature, and the characteristics of the paint. With thin metal sheets this may have been about 30 min., but with heavy castings prolonged heating is necessary; for example, 4 hr. for a cast-iron object weighing 14 lb. Using the very much greater rates of heat transfer by radiation the times required to heat the objects are very much less, and the sheets requiring 30 min. in a convector oven can be dried in about 40 sec. and the heavy casting in 25 min. in the infra-red rays from a radiant source at 650°F., while by using a gas fire as source of infra-red at 1,600°F. the time required for the casting is only 4 min.

Many theories were put forward in the early stages of development to account for these very rapid drying times. Maxted states (3) that "when such results were first obtained they were frequently attributed to some catalytic or direct action of the radiation. The B.T.H. Company demonstrated in 1935 that this was not an explanation. Thus, identical enamelled steel sheets were heated by irradiating in one case the painted face, and in the other the back surface; similar results were obtained at similar baking temperatures."

In order to take full advantage of the high rates of radiant heat

* From a Paper to the Institute of Fuel, July 21.

transfer and rapid attainment of a higher paint temperature, it is essential that full information should be available from the paint manufacturer about paint characteristics and the effects of actual paint temperature. The minimum information needed is:

(*a*) The drying time needed at different paint temperatures.
(*b*) The minimum time in which spoiling takes place at these different temperatures.

It will then be possible to give the correct practical margin between rapid drying and possible spoiling of the paint.

Convection or Radiant Heating?

The widespread successful use of convector ovens makes it necessary to give some analysis of the relative merits of both convection and radiation heating, since the early enthusiasm for infra-red drying has tended to create the impression that convector ovens are out of date and that they will be displaced by infra-red heating. It is true that many processes now carried out in convector ovens can be more quickly and easily performed by infra-red, but equally true that for others convection heating must remain, though incidentally the work on infra-red has indicated methods of improving convector oven practice.

It is not generally recognized that in a convector oven a major portion of the heat transfer may take place by radiation. Taking as example a metal sheet suspended in a convector oven so that it is under direct radiation from the walls—*i.e.*, not shielded by another sheet—the following figures indicate the relative influence of radiation and convection on heat transfer for a plate being heated from 60° to 220°F.

Oven temperature °F.		250.	300.	400.	500.	600.
Natural convection	Radiation %	64.5	65.3	68.2	72.2	76.0
	Convection %	35.5	34.7	31.8	27.8	24.0
Forced convection 5 ft. per sec.	Radiation %	47.7	48.1	49.0	52.0	57.4
	Convection %	52.3	51.9	51.0	48.0	42.6

For paint drying it has not been usual to operate with oven temperatures exceeding 350°F., and in a batch type oven the major heat transfer to articles in sight of the walls has been by radiation. Articles shielded from the walls are heated by convection and by radiation from work nearer the walls as this becomes heated more rapidly. It will be obvious that the oven temperature must not exceed the spoiling temperature of the paint (this frequently is within 50°F. of the drying temperature), otherwise the work nearest the walls will be burned, while the work in the centre of the oven may not be dried. This defect in the batch type oven is partially overcome by the forced convection conveyor oven, but since the walls of this type of oven are well insulated to prevent heat losses they will reach the circulating air temperature at which the oven operates. If, however, the convector oven can be used in such a way that articles passing through it are not shielded from direct radiation from the walls, the conveyor system can be accelerated so that the objects do not exceed the maximum safe temperature, and greatly increased rates of heating can be achieved, for in fact the convector oven has become an infra-red oven with the added advantage of convected heat transfer. The limiting factor is, however, the maximum temperature at which such an oven can be operated economically, and this remains for experiment to decide. It is doubtful, however, if this maximum is above 400°F., even with the best type of convector oven.

The following figures indicate the time taken for plates of different thickness to reach 220°F. in a convector oven at temperatures from 250° to 400°F. when shielded, and when in full view of the walls, and in two types of infra-red tunnel.

Gauge No. s.w.g.	Thickness In.	Time in minutes. Oven temperature °F. 250. Exposed.	250. Shielded.	300. Exposed.	300. Shielded.	400. Exposed.	400. Shielded.	Infra-red tunnel. 650°F.	Infra-red tunnel. 1,600°F.
22	0.031	2.4	6.8	1.4	3.8	0.8	2.2	0.7	—
16	0.062	4.7	13.3	2.8	7.6	1.5	4.4	1.25	—
14	0.078	5.9	16.7	3.6	9.8	1.9	5.6	1.5	—
12	0.099	7.4	21.0	4.5	12.3	2.5	7.2	1.9	—
10	0.125	9.3	26.3	5.6	15.3	3.1	9.0	2.5	—
4	0.25	18.6	52.6	11.2	30.5	6.2	18.0	5.0	0.25
—	0.5	37.2	105.0	22.4	61.2	12.3	35.7	10.6	0.5

It will be seen from these figures for the infra-red tunnel that precise timing is very important, for if the heating period is extended the paint will be spoiled. The amazingly short times with the high temperature panel make the use of such panels difficult for paint drying except on heavy objects.

It must be mentioned that with both the medium temperature and the high temperature infra-red tunnels the temperature of the air in the tunnel is only about 25°F. above atmospheric temperature.

The advantages of infra-red drying are most marked when large numbers of the same object have to be treated, and where each article can pass through the oven without being shadowed by its neighbours from the walls of the tunnel. Simple shapes with approximately the same surface to weight ratio are easiest to process, and articles with re-entrant angles require special care so that the heating of the shadowed portions by conduction will proceed at approximately the same rate as the parts exposed to direct radiation.

Drying on Surfaces Shielded from Direct Radiation

In practice it frequently happens that objects to be dried have an irregular shape with handles or other projections which shield certain parts of the surface; an extreme instance is the drying of petrol cans which have been painted internally as well as externally. Heat can only reach the shielded areas by conduction through the metal, and the temperature rise required to bring about curing of the paint must be obtained by this means. In the convector oven, which depended for its success on bringing the whole article up to temperature, this was no difficulty, as the rate of heat transfer through the metal by conduction is greater than the rate at which heat can be transferred from the oven by convection, so that even thick metal objects were uniformly heated, and all surfaces were dried to the same extent. With the very much higher rates of heat transfer possible with infra-red, the problem of even heating throughout the metal when shielded surfaces have to be dried becomes important. Experiments show that steel up to 0.125 in. thick shows no appreciable temperature gradient with the medium temperature panels at temperatures up to 250°F.; with thicker sheets the gradient becomes noticeable, and is about 20°F. for a thickness of ½ in. at 250°F. With the high temperature panels the effect is more pronounced, and with the ½-in. sheet heated to 250°F. on the exposed surface in 9 min. the internal surface is 50°F. lower. It will be realized that if a paint requires a temperature of 230°F. for drying, but would spoil at 270°F., the high temperature source could not be used if the internal surface of an object ½ in. thick is to be dried. The medium temperature source could be used, however, and this would still represent a considerable saving in time over the convector oven. In a practical test using copal varnish on cast-iron cylindrical objects ½ in. thick, 4½ in. outside diameter, it was found that both surfaces were dry after 26 min. in the medium temperature oven, whereas the time taken in a convector oven was 4 hr. In the high temperature radiant tunnels the paint on the outside was found to burn within 5 min., while inside it remained wet.

With sheet metal articles up to 0.125 in. thick, no difficulty has been experienced with either the medium or high temperature infra-red tunnels.

Practical Sources of Infra-Red Rays

It should already be clear that a source of infra-red rays is simply a source of radiant heat giving radiation mainly of wave-lengths longer than those visible to the human eye—*i.e.*, longer than about 7,000 A.U. All the familiar radiant heaters, gas fires, gas grills, electric fires, electric bulbs, &c., emit nearly all their radiant energy in the infra-red region.

The practical problem is to produce radiation economically; this radiation must give a suitable and reasonably uniform intensity over the whole surface of the object to be heated, and it must be substantially absorbed by the surface on which it falls.

Suitable Intensities of Radiation.—It has been common practice in electric infra-red paint drying to obtain a flux density of the order of 3 to 6 watts per sq. in. falling on the working plane—this would mean 1½ to 3 watts per sq. in. on each side of a metal sheet placed in this plane. The equivalent in terms of units normally used by the Gas Industry is 1 watt sq. in. = 490 B.Th.U. per sq. ft. per hour, and therefore a total flux density of the order of 750 to 1,500 B.Th.U. per sq. ft. per hour is likely to be suitable for many paint-drying purposes, and this has proved to be so in practice for dealing with sheet metal objects. Much higher intensities are, however, needed for the heating of heavy objects, and it is practical to go as high as 100 watts sq. in. or about 50,000 B.Th.U. per sq. ft. per hour, if gas is used as the source of heat.

These intensities can be obtained by using sources of either a large area at a comparatively low temperature or a small area at a high temperature. It is possible to arrange either to surround the object to be heated almost completely by a source of large area or by spaced sources of small area, giving a similar total radiant heat output.

The following Table I gives an idea of the flux density obtained if an object is completely surrounded by the source:

TABLE I.

Source temp. °F.	Flux density.* B.Th.U./sq. ft./hour.	(Effective flux density—heated object at 220°F.) B.Th.U./sq. ft./hour.
400	1,600	900
600	4,000	3,300
1,000	9,000	8,300
1,500	25,000	24,300
2,000	63,000	62,300

* These values include radiation from all directions—*e.g.*, for a sheet metal plate half this flux density falls on each side of the plate.

(To be continued)

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Gas Products Prices

The London Market July 26.

All Coal Tar Products are in good demand, and Pitch in the London area remains about 45s.

A new Order entitled The Control of Toluene (No. 3) Order, 1943 (S. R. & O. 1943, No. 976), came into force on July 20, and introduces certain changes in the prices for different grades of Toluene.

Apart from this there are no changes to report in Tar Products prices.

The Provinces July 26.

The average prices of gas-works products during the week were: Pitch and Crude Tar,* Toluole, naked, North, 90's, 1s. 10d., pure, 2s. 5d. (controlled by the Control of Toluene No. 2 Order, July 3, 1941, which fixes the maximum price at which this material may be sold). Naphtha and Xylole controlled by the Coal Tar Naphtha and Xylole Order, 1943, dated May 31 (S. R. & O., 1943, No. 768), operative from June 1. Carbolic acid, 60's, naphthalene, and anthracene controlled by the Coal Tar Products Prices Order S. R. & O. 2509, dated Dec. 7, 1942, and operative from Jan. 1, 1943. Filtered heavy oil (min. gr. 1,080), 7¼d. to 8d. Creosote oil has been generally controlled as to direction and price for some time past. Current value—fuel grades 5d. to 5¼d.; timber preservation and other purposes 4¾d. to 6d.

* In regard to pitch and crude tar prices we would ask readers to refer to the editorial note on p. 396 of the "JOURNAL" for Sept. 10, 1941.

Tar Products in Scotland July 24.

Being "Glasgow Fair" week, opportunity has been taken for general overhaul of plant. Refined tar controlled. Value is 4½d. per gallon *ex* Works, naked. Creosote oil: Specification oil, 6½d. to 7d.; low gravity, 7¼d. to 7½d.; neutral oil, 6d. to 6½d.; hydrogenation oil, 5⅞d. per gallon; all *ex* Works in bulk. Refined cresylic acid is available at 3s. 6d. to 4s. 6d. per gallon *ex* Works, naked, according to quality. Crude naphtha, 6½d. to 7d. per gallon. Solvent naphtha: Basic prices delivered in bulk, 90/180 grade 2s. 8d., and 90/190 Heavy naphtha, Unrectified, 1s. 10½d.; Rectified, 2s. 3d. per gallon. Pyridine: 90/160 grade, 13s., and 90/140 grade, 15s. per gallon.

Gas Stocks and Shares

The buying of industrial shares remained the feature of the stock markets last week and a number of sharp gains were recorded. British Funds were weak at the opening, but rallied towards the close. Marks received were considerably more than the previous week.

There was also more business in the Gas Market, and with only one exception, that of Imperial Continental, which fell a further point, prices continued firm with a tendency here and there to move up. A strong feature last week was the sharp rise of 9½ points in Alliance and Dublin to 95, the last transaction being recorded at 86 last month. Commercial 5% debenture, which changed hands at 110½, closed 3 points up at this price and appears to be considerably undervalued.

The following price changes occurred during the week:

OFFICIAL LIST		
Alliance & Dublin Ord.	90—100	+9½
Cardiff Ord. (x.d.)	110—115	July 19
Commercial 5 p.c. Deb.	108—113	+3
Gas Consolidation "B" Ord. ...	17/6—19/6	+1/-
Imperial Continental Ord.	87—90	-1
Severn Valley 4½ p.c. Cum. Pref. ...	20/—21/-	+-/6d.
South Suburban Ord.	96—101	+1
Southampton Ord.	87—92	+2
PROVINCIAL EXCHANGES		
Sheffield Ord.	138—142	+2
Weston-Super-Mare Ord.	106—108	+2½

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GAS METERS